

This document reviews the changes in flow, water temperature, dissolved oxygen (DO), pH, fecal coliform bacteria (FC bacteria), total suspended solids (TSS), and turbidity in Icicle Creek due to the operations of the Leavenworth National Fish Hatchery (LNFH). A QUAL2K water quality model (Chapra et al, 2003) developed and calibrated for the 2002 TMDL study in the Wenatchee basin (Carroll et al, 2006) was used to simulate water quality changes to water temperature, DO, and pH.

For the model simulations with and without the hatchery presence, two flow and meteorological conditions were simulated to give a range of conditions during the critical part of the year for water quality in Icicle Creek. The two flow conditions simulated were:

- August flow condition (used August 2002 conditions which were a little higher than a 7Q2 flow condition with warm mid-summer temperature conditions)
- September flow condition (used late September 2002 which was close to a 7Q10 critical low flow, with cooler fall conditions).

Graphs in Figure 1 shows the August and September flow balances in Icicle Creek without the hatchery presence. For the simulations without the presence of the hatchery the following assumptions were used:

- Headwater and groundwater inflow plus tributary flow for headwaters, Jack Creek, and Eightmile Creek were the same as the August 2002 and September 2002 flow balances.
- Using the recession baseflow record for Snow Creek that you sent me, I input an 8.4 cfs baseflow for August and 3.8 cfs baseflow for September (respective averages for those months) in Snow Creek without the hatchery presence.
- A water right diversion of 7.0 cfs for Cascade Orchard Irrigation was diverted from Icicle Creek at the LNFH diversion point.
- All flow in Icicle Creek was routed down the old channel in the simulation without the hatchery complex.

Graphs in Figure 2 show the August and September flow balances in Icicle Creek with the hatchery presence. For the simulations with the presence of the hatchery the following assumptions were used:

- Headwater and groundwater inflow plus tributary flow for headwaters, Jack Creek, and Eightmile Creek were the same as the August 2002 and September 2002 flow balances.
- With the hatchery presence, a 50 cfs flow was used for Snow Creek in both August and September, as you requested.
- The same August 2002 flow diversion down the hatchery canal was simulated the in August simulation. All flow in Icicle Creek was routed down the old channel in the September simulation.
- Hatchery diversion and return were the same as in 2002, and includes some supplemental flow return from well pumping.

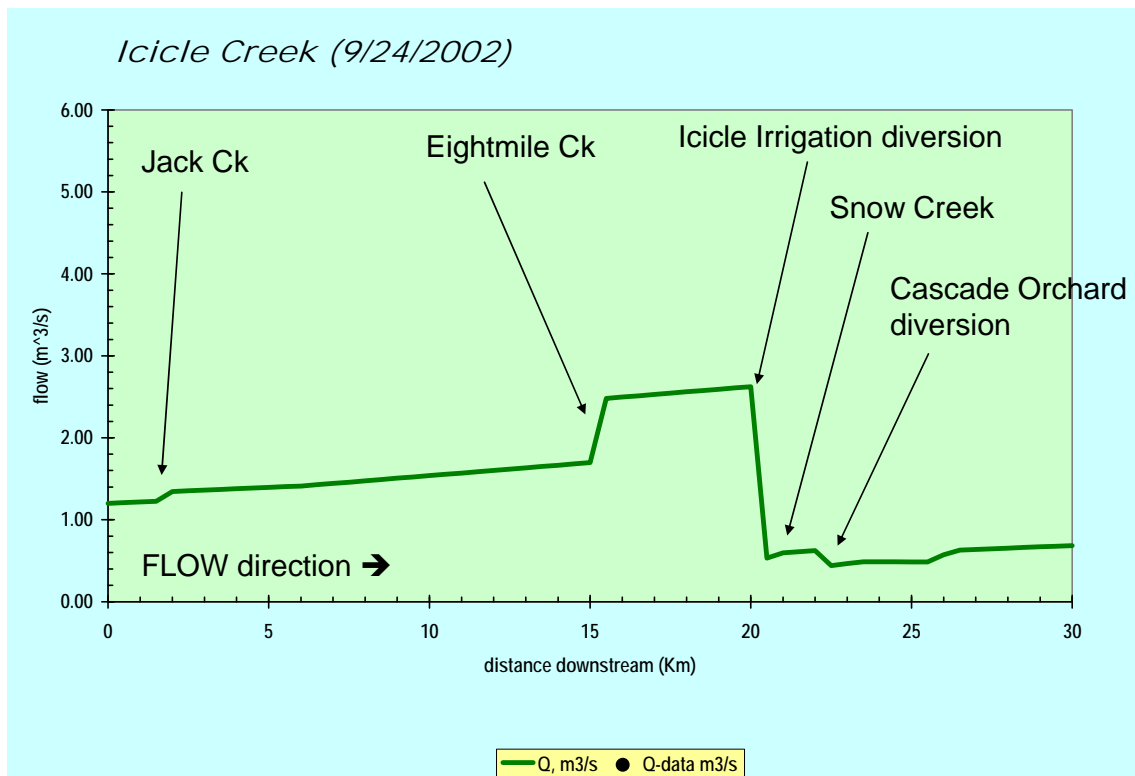
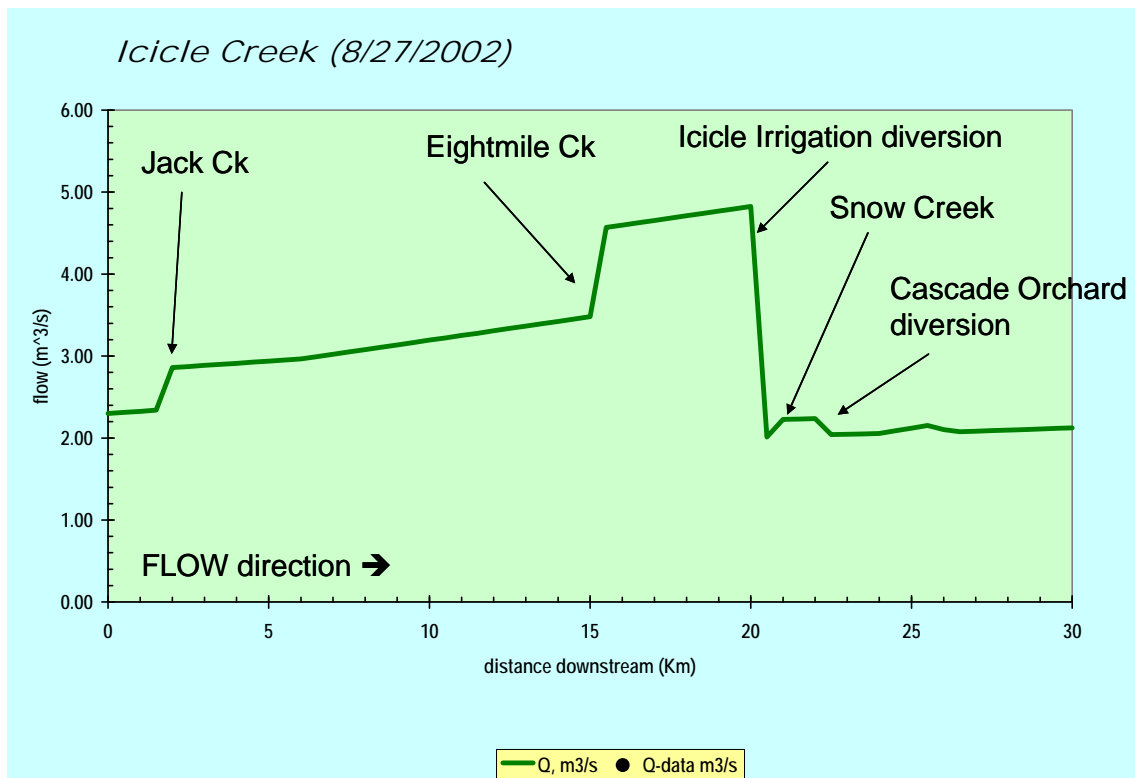


Figure 1. Simulated flow balances without hatchery presence for August and September flow conditions.

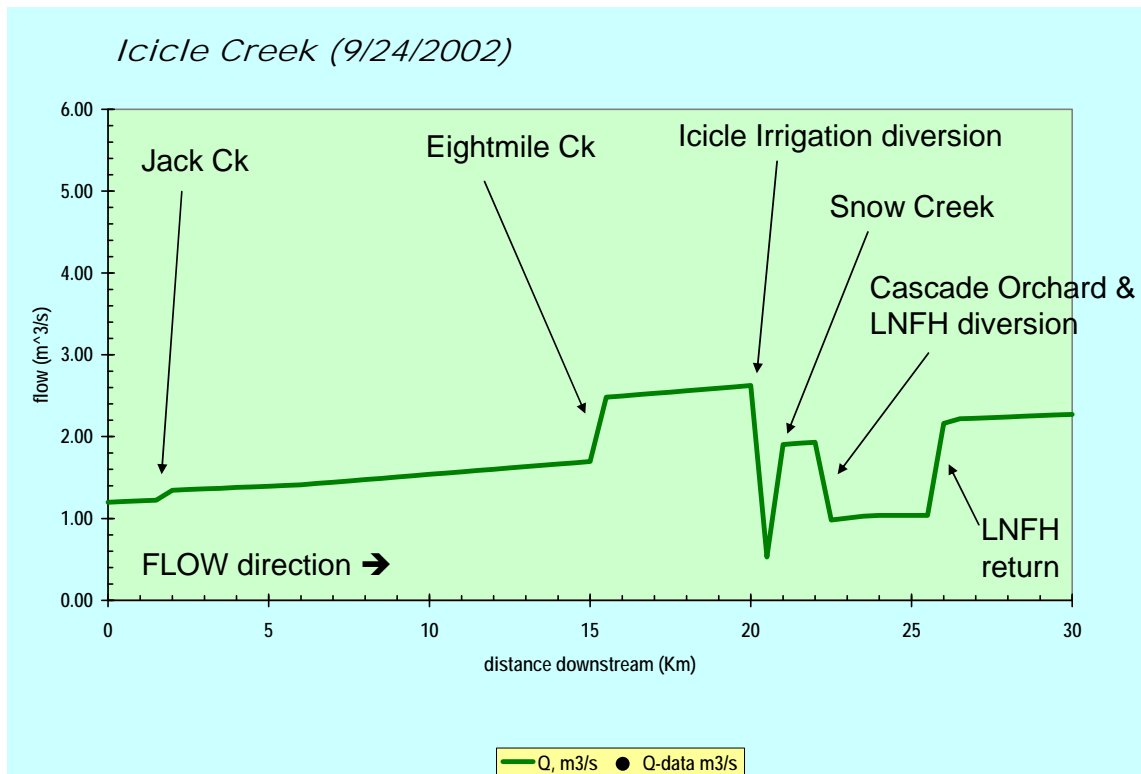
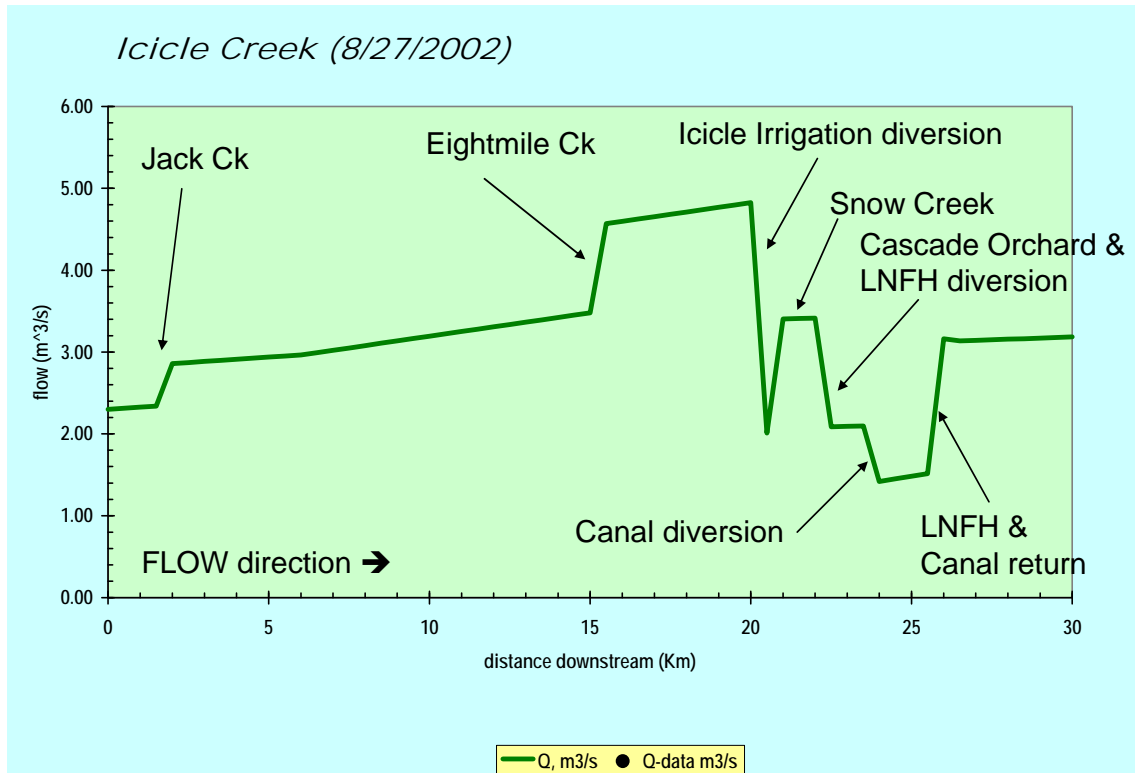


Figure 2. Simulated flow with hatchery presence for August and September flow conditions.

The addition of 50 cfs from Snow Creek in September distinctly changes the flow balance from that seen in September 2002 (Figure 3). In 2002 there was just under 17 cfs in Snow Creek. Icicle Creek was almost dewatered between the LNFH diversion and the LNFH return. This meant that almost all of the flow in lower Icicle Creek was from the hatchery facility (i.e., the hatchery had a dilution ratio of nearly one – no mixing zone). The water quality results using a 50 cfs flow in Snow Creek will be different from the 2002 TMDL water quality results.

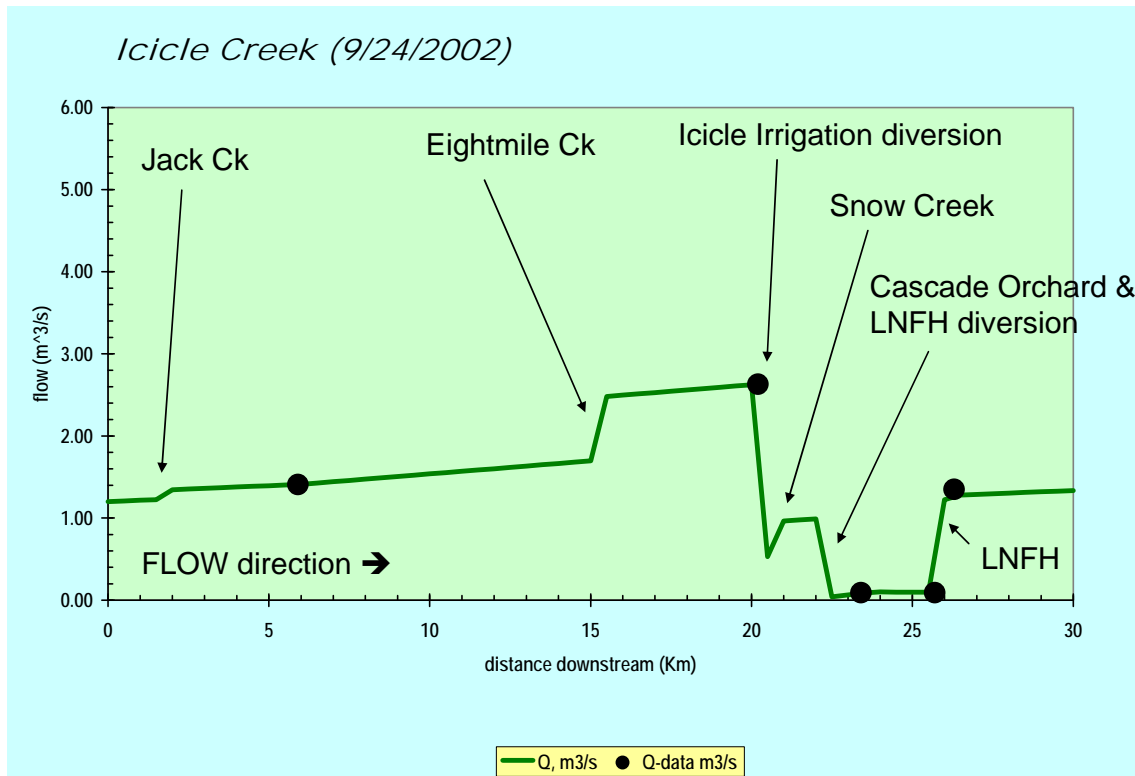


Figure 3. Simulated flow balance in September 2002. Critical conditions for the TMDL in Icicle Creek were based on these flow conditions.

Using the flow balances described above, water temperature, dissolved oxygen, and pH were simulated in Icicle Creek with and without the hatchery presence. Water temperature was simulated using the 2002 shade measured and calculated for the 2002 temperature TMDL (Cristea and Pelletier, 2005). Meteorology from August and September 2002 was also used in the simulations. Figure 4 shows that the addition of 50 cfs from Snow Creek, which has cooler temperatures, is expected to lower the water temperature of Icicle Creek after mixing. Additionally, the LNFH outflow is expected to further cool Icicle Creek, due to the transport and discharge of cooler Snow Creek water through the facility and perhaps also due to the addition of colder groundwater in the hatchery outflow. The temperature cooling effect of the LNFH operations, particularly the addition of colder Snow Creek water, is also expected to increase DO in Icicle Creek (Figure 5). This is mainly due to higher saturation conditions for dissolved oxygen in the cooler water, although there may have been some increase in downstream DO due to increased primary productivity as well.

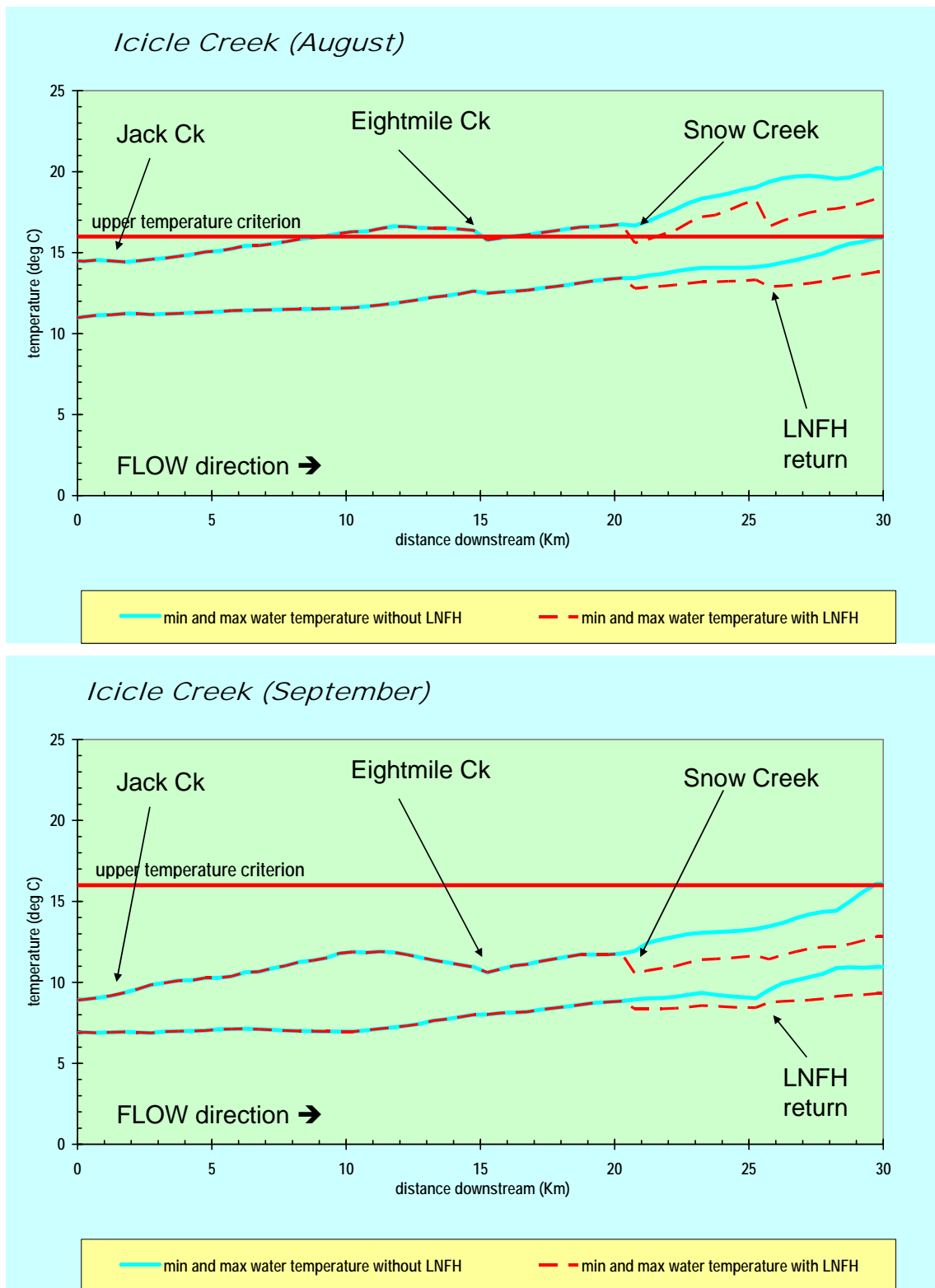


Figure 4. Differences in water temperature with and without the LNFH during typical flow conditions found in August and critical low-flow conditions found in September.

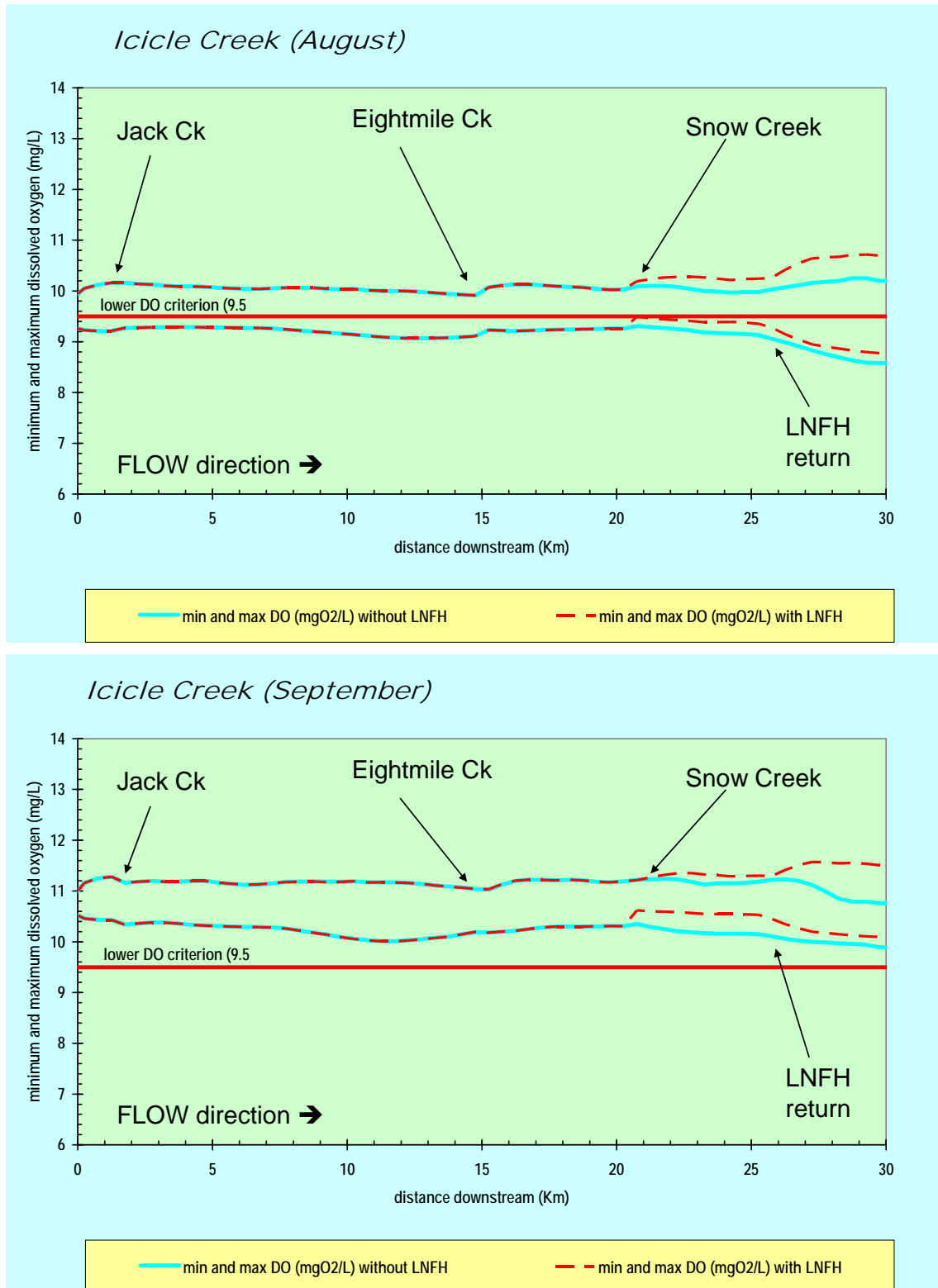


Figure 5. Simulated minimum and maximum dissolved oxygen in Icicle Creek with and without LNFH operations for August and September flow conditions.

The increase in productivity in Icicle Creek is related to the concentration of phosphorus in the water because phosphorus is the most limiting nutrient in lower Icicle Creek (Carroll et al, 2006). The LNFH operations were the main cause of increased phosphorus loading to Icicle Creek in 2002, although there is some non-point loading in the lower reaches of Icicle Creek. Still, the LNFH discharge accounted for approximately 86% of the phosphorus loading to lower Icicle Creek in September 2002 (Carroll et al, 2006).

The LNFH has conducted some operational changes since 2002. A decrease in phosphorus concentration in the discharge under the bridge had taken place in 2007 compared 2002 concentrations (Table 1 and Table 2). Some of this is due to a decrease in the phosphorus concentration at the LNFH intake. Snow Creek has a very low concentration of phosphorus and made up a larger proportion of the LNFH intake water in 2007 than in 2002. Still, in both years there was about a 300% increase in phosphorus concentration at the outlet (under bridge) compared to the intake. The average increase was 7 ug/L in 2002 and 3.8 ug/L in 2007.

Table 1. Phosphorus concentrations in ug/L from samples at LNFH locations in 2002.

Date	Type of sample	Under bridge discharge <sup>a</sup>	Pond Effluent <sup>a</sup>	Intake <sup>a</sup>	Dam 5 <sup>a</sup>	E. Leavenworth bridge <sup>a</sup>
6/25/02	grab	8	28	< 3 <sup>b</sup>	4.3	3.3
7/22/02	grab	8	17	---	---	---
7/23/02	grab	---	27	< 3	3.5	3.1
7/23/02	composite	12	---	---	---	---
8/27/02	grab	13	---	< 3	5.2	8.5
8/28/02	grab	7	---	---	---	---
8/29/02	composite	---	66.5	---	---	---
9/24/02	grab	13	---	4.1	7.7	12
9/25/02	grab	14	---	---	---	---
9/25/02	composite	---	42	---	---	---
10/22/02	grab	6.9	12.5	4.2	4.3	5.7
4/8/03	grab	12	---	3.2	8.2	4.7
	<u>Average</u>	<b>10.4</b>	<b>32.2</b>	<b>3.4</b>	<b>5.5</b>	<b>6.2</b>
	<u>Maximum</u>	<b>14.0</b>	<b>66.5</b>	<b>4.2</b>	<b>8.2</b>	<b>12.0</b>

<sup>a</sup> Samples from 2002 are dissolved inorganic-P results.

<sup>b</sup> Results less than the reporting limit (<3.0) were calculated using the reporting limit.

Table 2. Phosphorus concentrations in ug/L from samples at LNFH locations in 2007.

Date	Type of sample	Under bridge discharge <sup>a</sup>	Pond Effluent <sup>a</sup>	Intake <sup>a</sup>	Dam 5 <sup>a</sup>	E. Leavenworth bridge <sup>a</sup>
7/11/07	grab	4.9	59.6	1.2	27.7	2.3
7/30/07	grab	6.2	70.3	3.2	4.2	4.6
8/22/07	grab	6.0	58.8	1.4	1.4	4.6
9/11/07	grab	3.5	49.7	1.8	2.0	5.4
9/13/07	grab	---	22.2	1.8	6.0	13.1
9/18/07	grab	5.6	85.8	1.4	2.3	4.1
10/2/07	grab	7	104	1.4	1.4	3.3
	<u>Average</u>	<b>5.5</b>	<b>64.3</b>	<b>1.7</b>	<b>6.4</b>	<b>5.3</b>
	<u>Maximum</u>	<b>7.0</b>	<b>104</b>	<b>3.2</b>	<b>27.7</b>	<b>13.1</b>

<sup>a</sup> Samples from 2007 are total phosphorus results.

For the pH simulations, the 2007 average phosphorus concentration of 5.5 ug/L was used for the LNFH discharge under the bridge and 64.3 ug/L was used for the LNFH abatement pond discharge. The pH of Snow Creek ranged between 7.00 and 7.24 in 2002, and since pH measurements from 2007 were not available, the 2002 data was used for this analysis. Since there is a larger proportion of Snow Creek water in the LNFH intake, there is reason to believe that the pH of the LNFH discharge may have been different in 2007; however, the pH of the LNFH discharge was also not measured in 2007, so the pH range from the 2002 TMDL study was used.

The model simulations predict there will be a pH changes greater than 0.1 pH units due to the LNFH operations as currently configured (Figure 6). These changes are greater than the measurable change allowed by the water quality standard antidegradation rules.

A pH change in Icicle Creek above the LNFH intake is expected due to the large inflow of lower pH Snow Creek water. After mixing with upstream water, the pH below the Snow Creek confluence is expected to lower 0.2 to 0.4 pH units. This is simply a change in the mass balance of hydrogen ion concentration from the mixing of lower pH Snow Creek water with upstream Icicle Creek water.

Similarly, at the LNFH discharge mixing zone, a pH change is expected as the lower pH LNFH discharge water mixes with the higher pH instream water. However, an increase in pH range further downstream of the LNFH discharge is expected from increased productivity in that part of Icicle Creek that results from the additional phosphorus loading of the LNFH discharges.



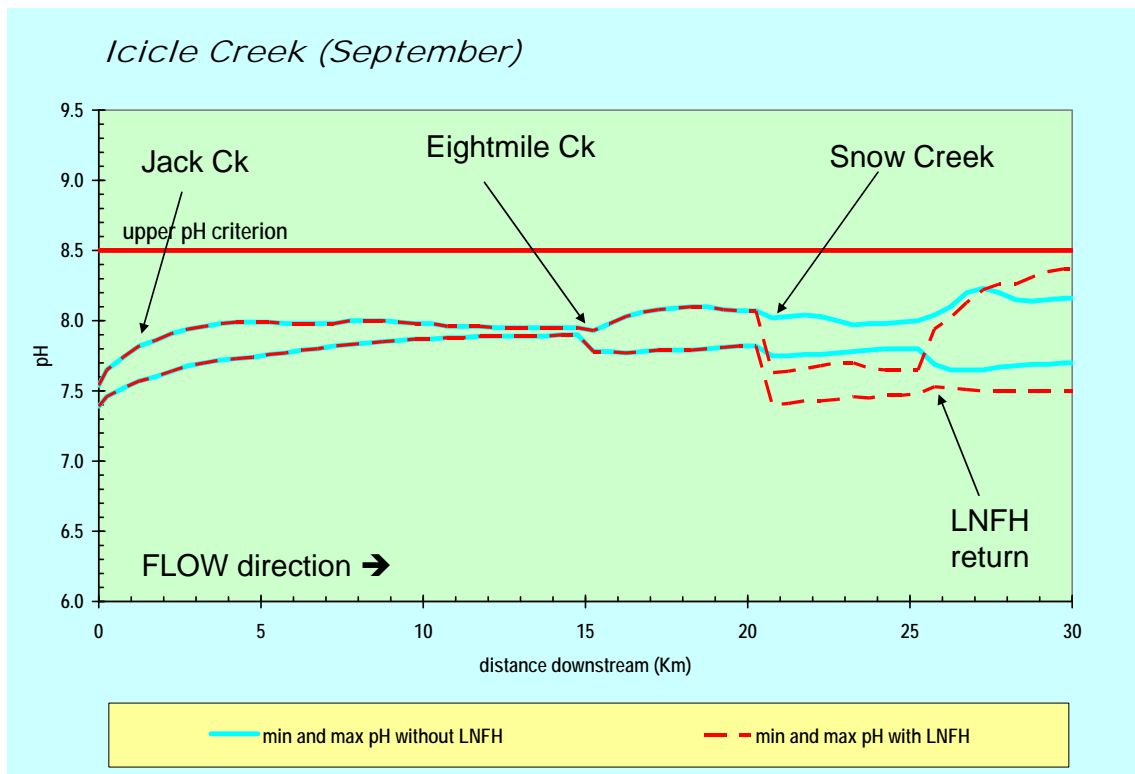
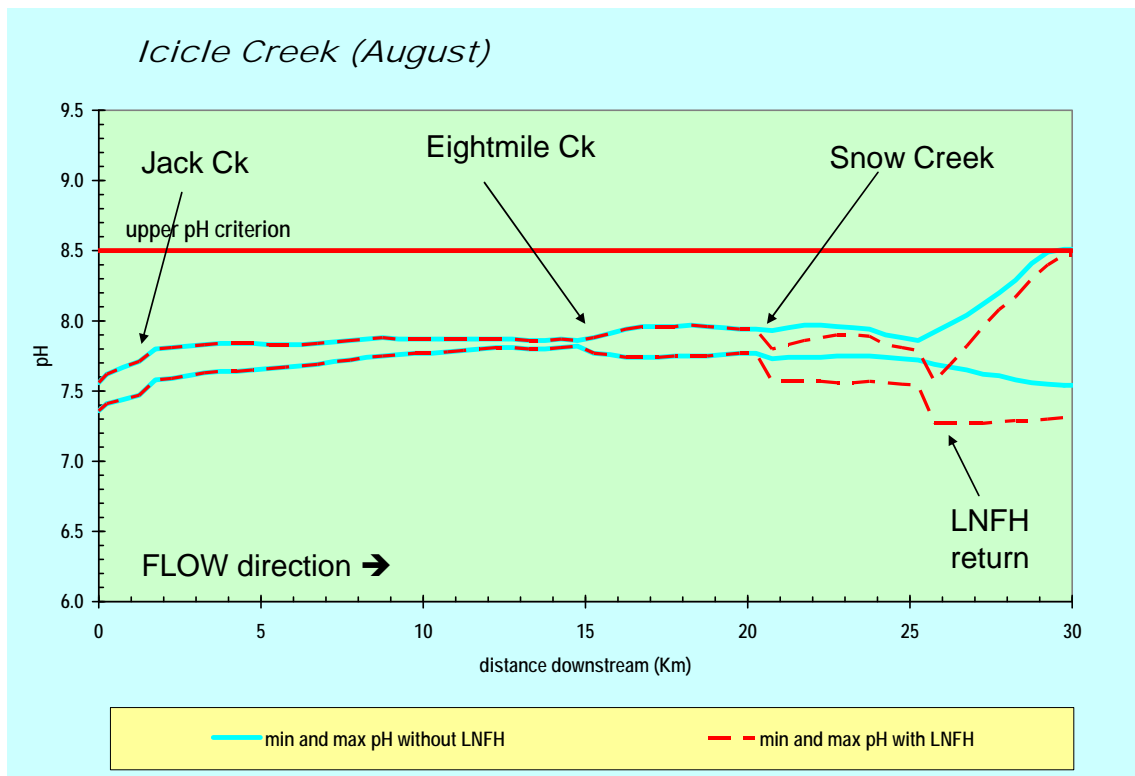


Figure 6. Simulated minimum and maximum pH in Icicle Creek with and without LNFH operations for August and September flow conditions.

Fecal coliform bacteria and TSS/turbidity data were not modeled because the Icicle Creek model is not calibrated for those parameters. However, a review of the available data collected in 2002-03 shows that the hatchery had no impact on downstream FC bacteria concentrations. Figure 7 shows fecal coliform data collected in 2002-03 in Icicle Creek. There were generally higher concentrations of FC bacteria below the LNFH outfall at RM 3.0 than above, but the LNFH outfall consistently had low concentrations (1-2 cfu/100mL) which suggest that the increases were not from the hatchery operations. The LNFH data included measurements in both the main outfall and the abatement pond discharge.

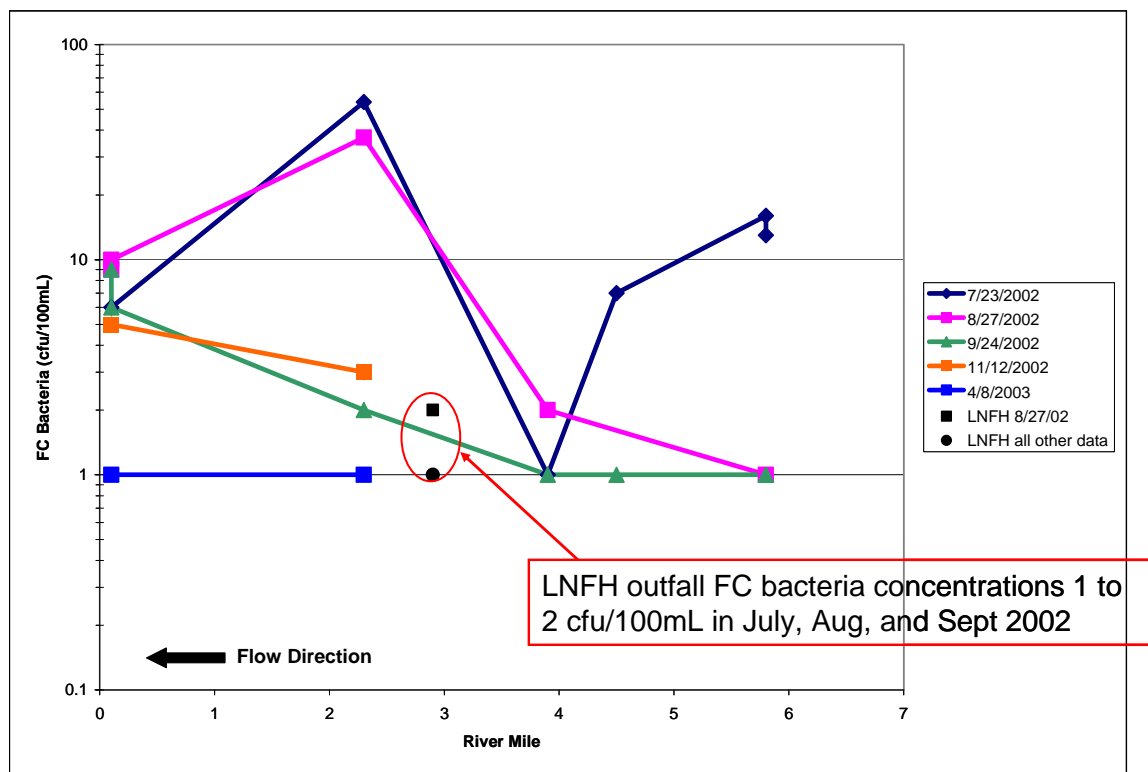


Figure 7. Fecal coliform bacteria concentrations by river mile in Icicle Creek from sampling done summer and fall of 2002 and April 2003. Concentrations of FC bacteria from the LNFH outfall are also plotted at discharge point (RM3.0) in creek.

Likewise, a review of the TSS data from 2002 shows the LNFH had no impact on downstream TSS concentrations in Icicle Creek. Figure 8 shows TSS data collected in 2002-03 in Icicle Creek. There were generally higher concentrations of TSS below the LNFH outfall (at RM 3.0) than above, but the LNFH outfall consistently had a low TSS concentration below 1 mg/L (2 mg/L in June sample only) which suggest that the increases were not from the hatchery operations. The LNFH data included measurements in both the main outfall and the abatement pond discharge.

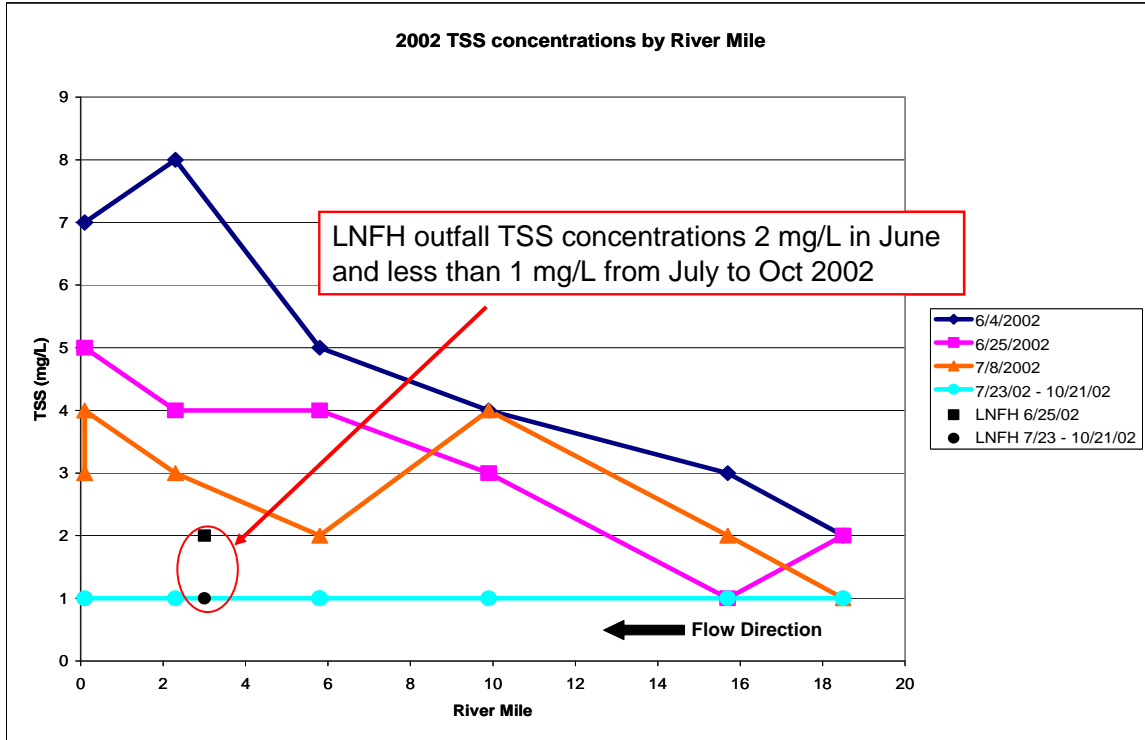


Figure 8. Total suspended solids concentrations by river mile in Icicle Creek from sampling done summer and fall of 2002. Concentrations of TSS from the LNFH outfall are also plotted at discharge point (RM 3.0) in creek.

During higher runoff times (June and early July) there is a general increase in TSS concentrations going downstream from the headwaters. The average slope of the concentrations by river mile suggests an approximate 0.3 mg/L increase in TSS for each river mile of water transport. During lower flows from late July through October, the TSS levels were always at or below the reporting limit of 1.0 mg/L.

In terms of an antidegradation analysis regarding a change in turbidity caused by the LNFH facility, the TSS results can be translated to turbidity results by the general relationship shown in Figure 9. This relationship shows that there is approximately a 0.26 NTU increase in turbidity for every 1.0 mg/L increase in TSS concentration. To keep actions from having a 0.5 NTU or greater measurable change in increased turbidity, increases in downstream TSS concentrations due to the LNFH would need to be kept below 2 mg/L. Again, there is no indication that the LNFH is causing any increase in downstream TSS concentrations.

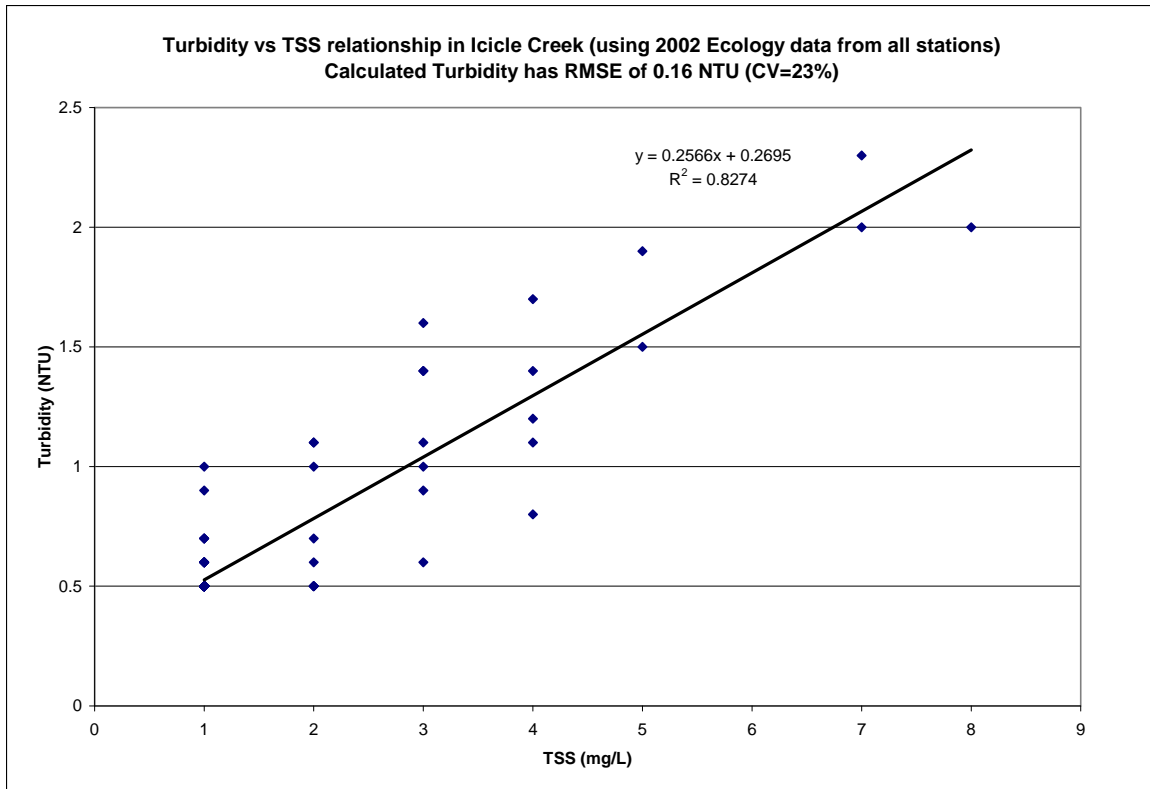


Figure 9. Turbidity and total suspended solids relationship in Icicle Creek using Ecology data from 2002 and 2003.

In summary, the LNFH operations are expected to change the flow balance in lower Icicle Creek, particularly due to the managed addition of 50 cfs to Icicle Creek from Snow Creek. While improvements in water temperature and dissolved oxygen are expected from the LNFH operations, model simulations predict there will be greater than a 0.1 unit change in pH due to the LNFH operations. Available data from 2002 synoptic surveys did not show any downstream increase in fecal coliform bacteria or turbidity due to the LNFH operations.

Hope all of this is helpful, Jim Carroll

#### References:

Carroll, J., S. O'Neal, and S. Golding, 2006. Wenatchee River Basin Dissolved Oxygen, pH, and Phosphorus TMDL Study. Washington State Department of Ecology. Publication number 06-03-018. <http://www.ecy.wa.gov/biblio/0603018.html>.

Chapra, S. and G. Pelletier, 2003. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Cristea, N. and G. Pelletier, 2005. Wenatchee River Temperature Total Maximum Daily Load Study. Washington State Department of Ecology. Publication number 05-03-011. <http://www.ecy.wa.gov/biblio/0503011.html>.